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(54) Abstract Title

Window milling and measurement apparatus with bypass valve

(57) A one trip apparatus and method involves a bypass valve 22 operated in conjunction with an MWD tool in a bottomhole assembly. The milling system 14 for the window, the whipstock 10, and the anchor are run in together with the bypass valve 22 and MWD tool. The whipstock 10 is oriented using the MWD tool with circulation through the bypass valve 22. The bypass valve 22 is actuated to close and lock to allow subsequent setting of the packer or bridge plug once the whipstock 10 has been properly orientated. The bypass valve 22 is movably responsive to fluid flow in a first direction and in an opposite second direction under a biasing force preferably a spring 46. The milling system is supported to the whipstock between a pair of blocks 106, Fig 2b and the mere rotation of the mills allows for formation of the window as the lower block 106 is milled away. The milling system 14 is held to the whipstock 10 with pins 146, Fig 3a through blocks. The pins 146 are capable of handling greater shear loads than shear pins which have in the past been used to secure the mills to the whipstock.

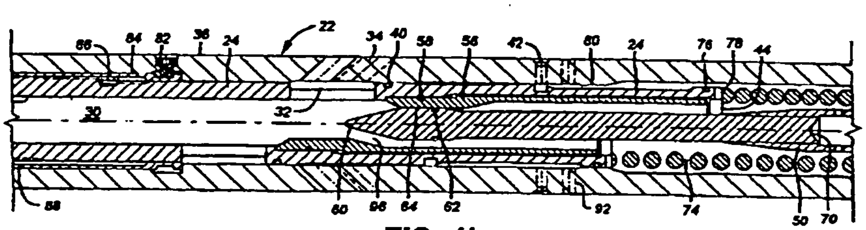

FIG. 1b

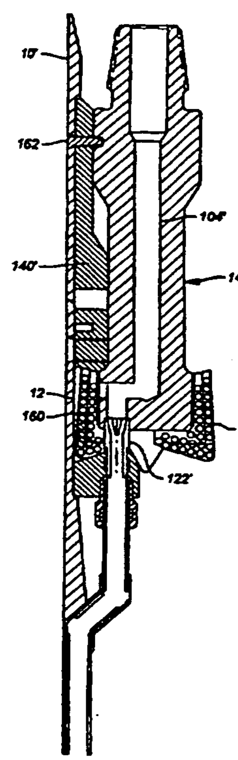

FIG. 4

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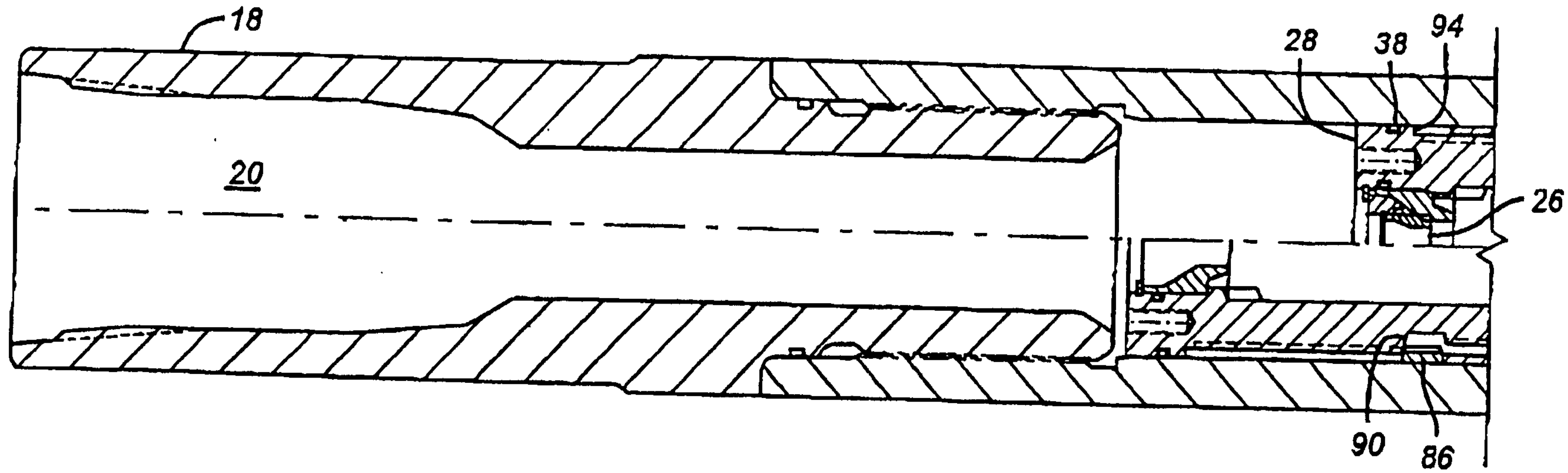

18
20
28
38
94
26
90
86

FIG. 1a

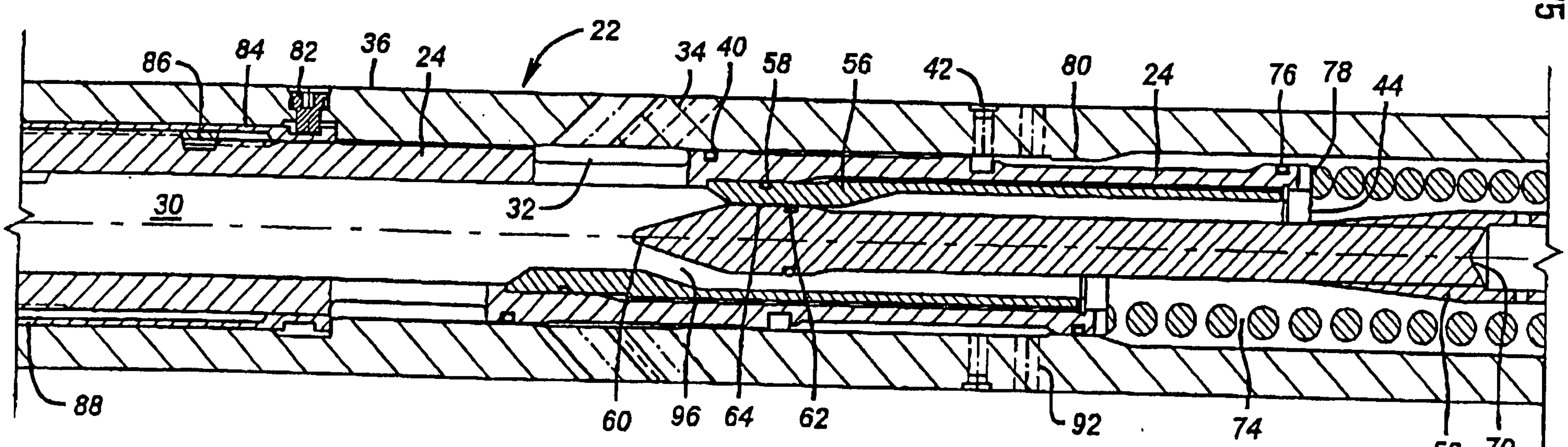

86
84
82
36
24
22
34
40
58
56
42
80
24
76
78
44
30
32
88
60
96
64
62
92
74
50
70

FIG. 1b

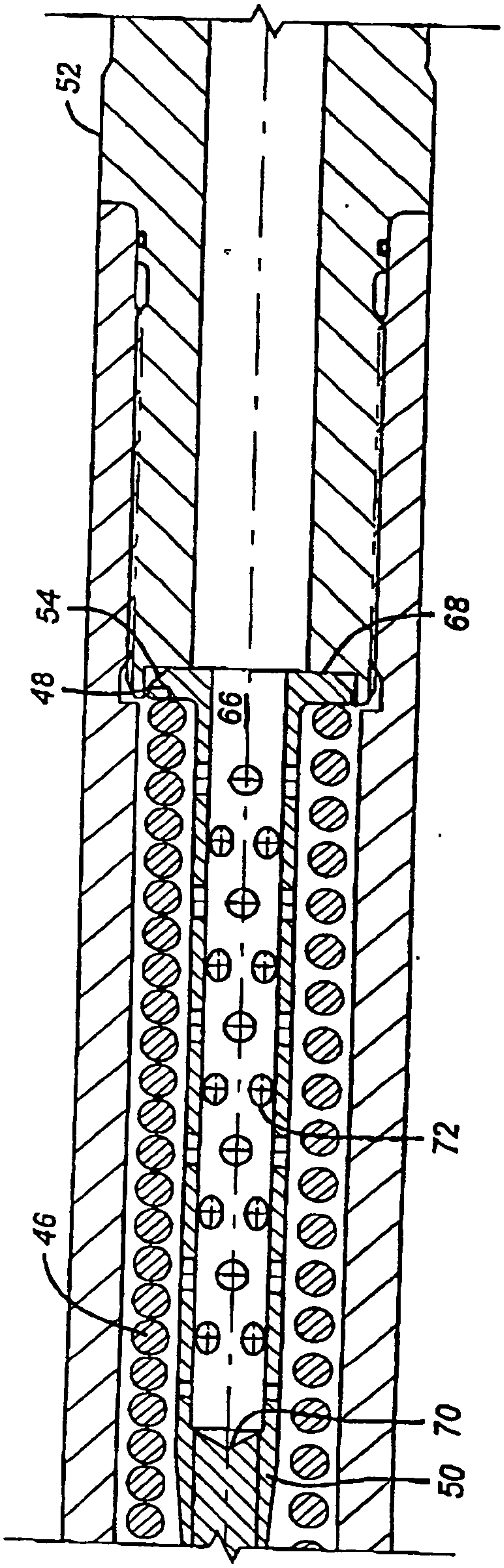


FIG. 1c

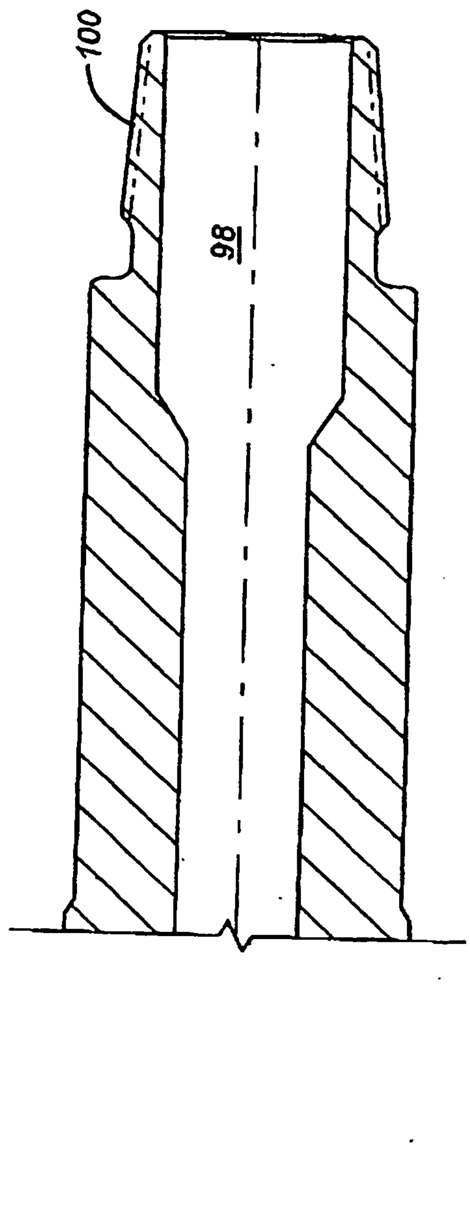
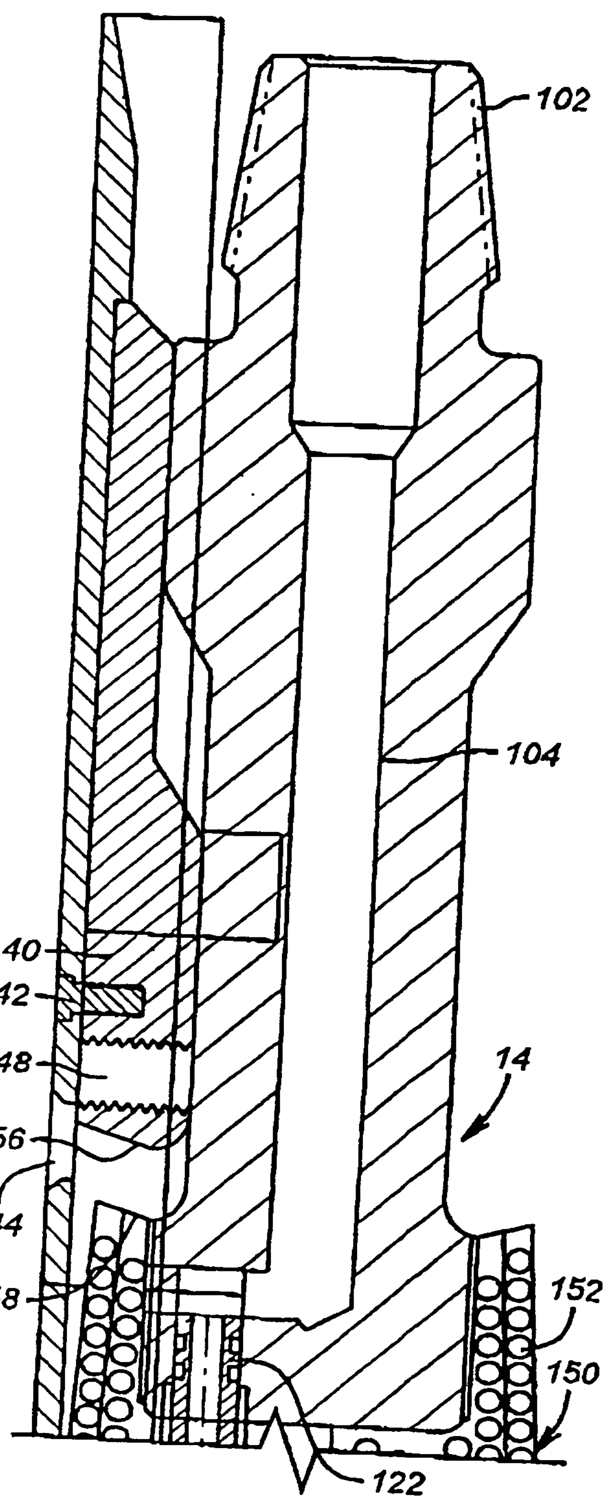
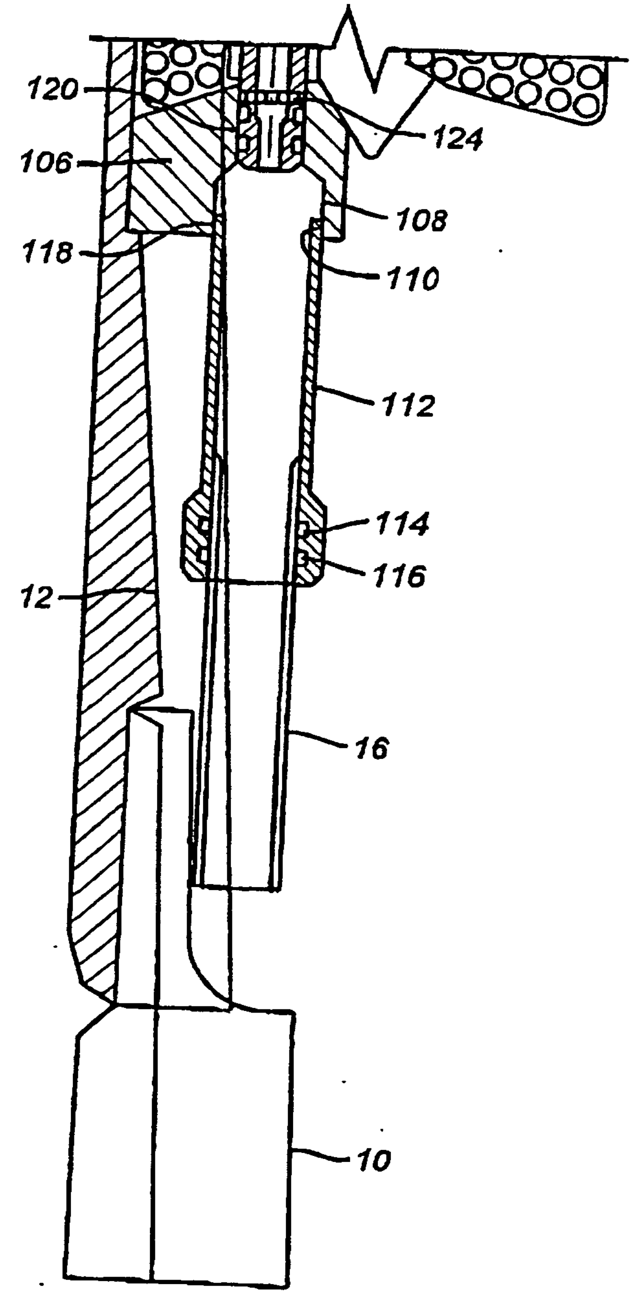


FIG. 1d


102
104
140
142
148
156
144
158
14
152
150
122
FIG. 2a


120
124
106
108
118
110
112
114
116
12
16
10
FIG. 2b

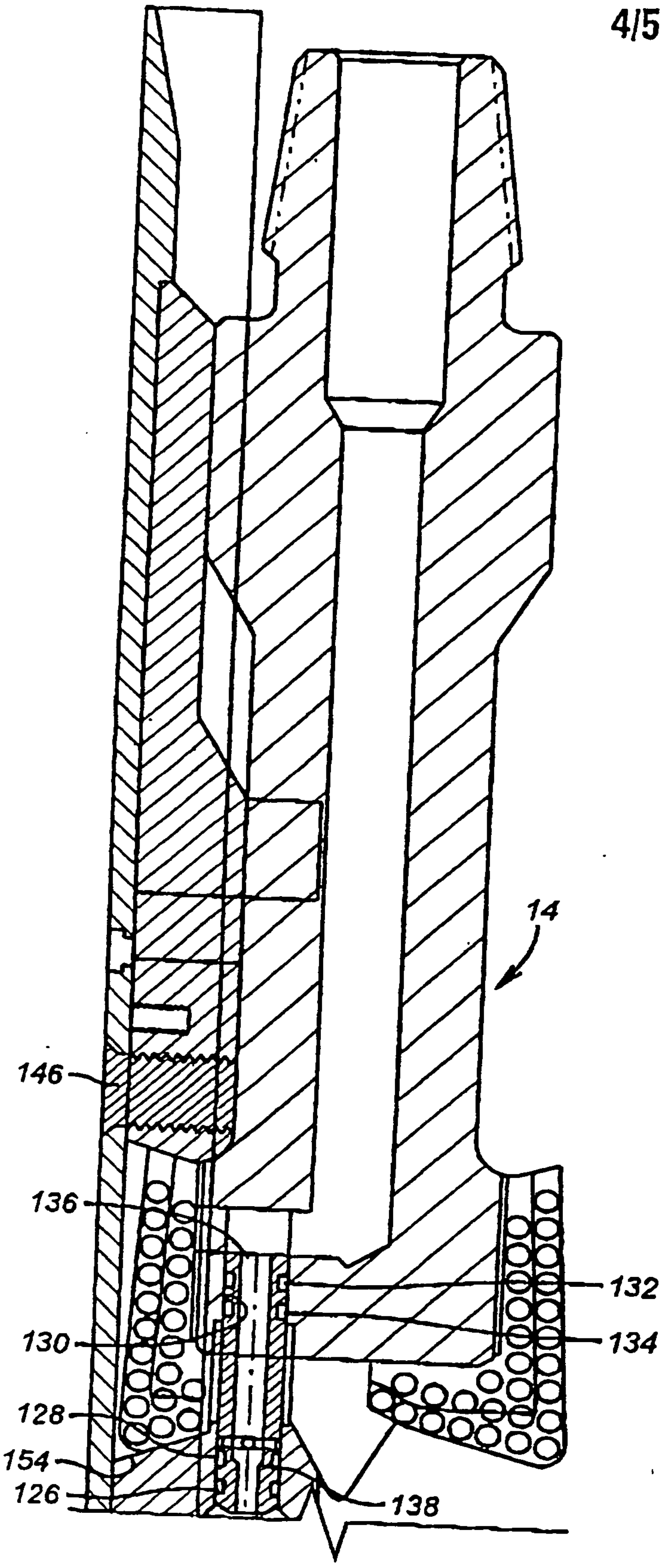


FIG.3a

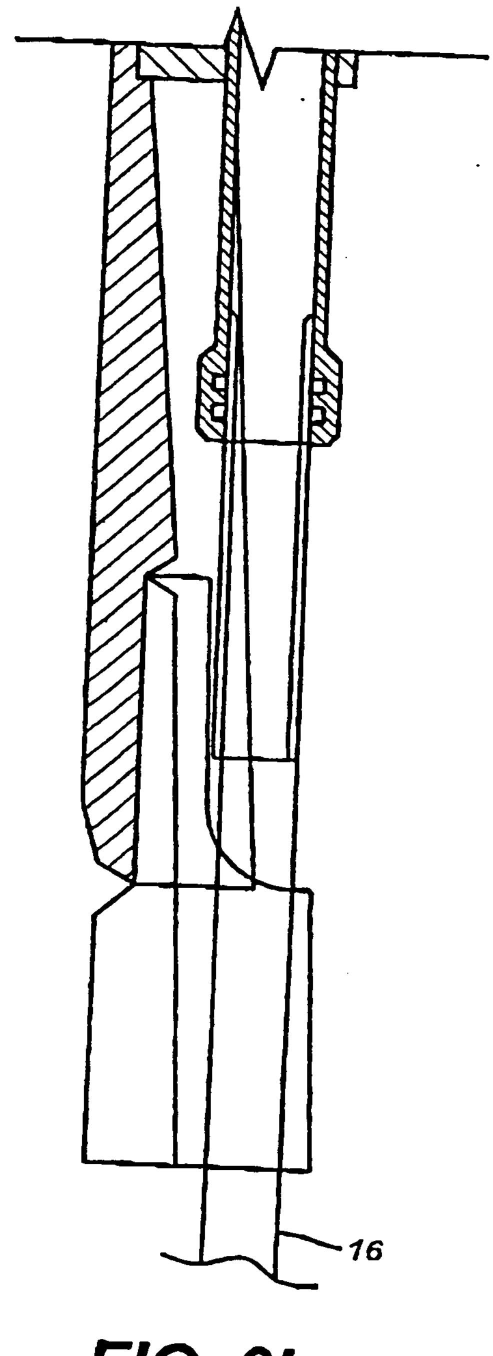


FIG. 3b

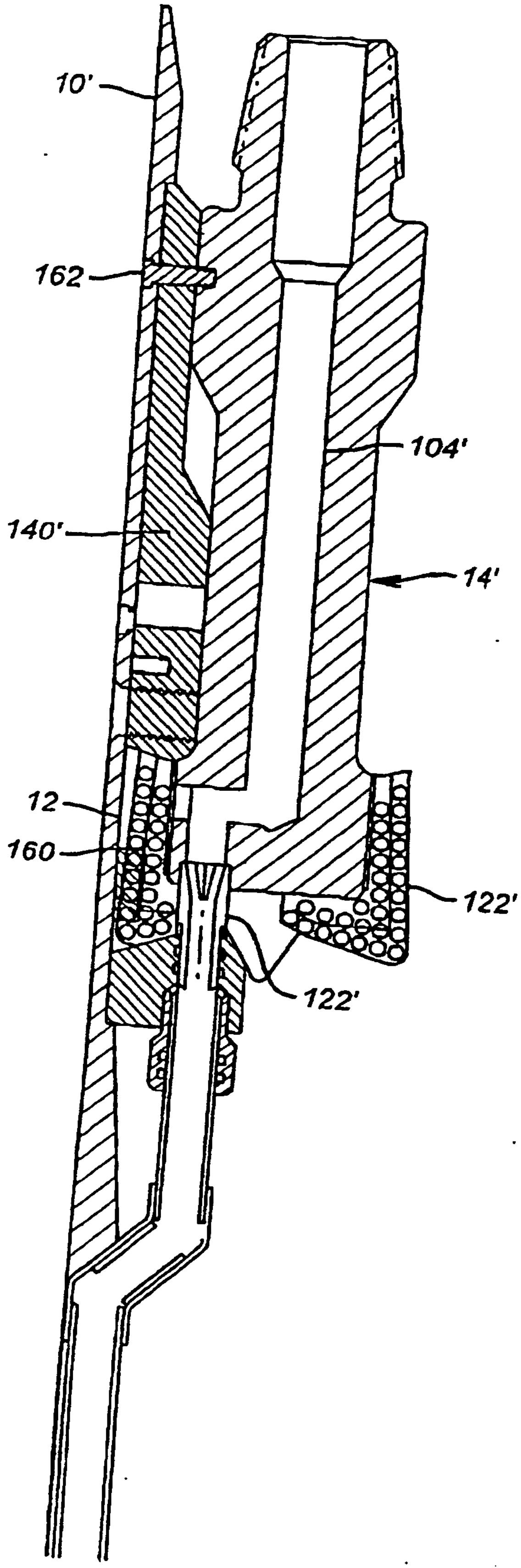


FIG. 4

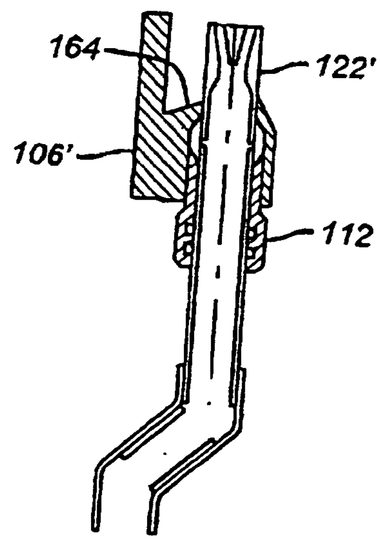


FIG. 5

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TITLE: **ONE-TRIP WINDOW MILLING APPARATUS & METHOD WITH MEASUREMENT-WHILE-DRILLING**

INVENTOR: MELVIN J. HARDY, ROY E. SWANSON, GREGORY L. HERN, and JOHN P. DAVIS

FIELD OF THE INVENTION

The field of this invention relates to orienting a whipstock and milling a window in a single trip.

BACKGROUND OF THE INVENTION

When milling openings in casing for laterals from existing wellbores, saving rig time is of utmost importance. Systems have been evolving to cut down the time necessary for milling a window by designing equipment and systems to minimize the number of trips into the wellbore to mill the window. In the past, systems have been developed to attach the complete series of mills required to mill the window to the whipstock when running in to eliminate subsequent trips to change mills during the forming of the window. With these systems, once the whipstock was properly set in the wellbore, the mills were already there, attached to it, and the window could be milled in a single trip in the wellbore, which allowed the whipstock to be anchored and the window to be milled. U.S. Patent 5,109,924, invented by *Jürgens*, illustrates one such system.

Other systems have sought to incorporate the orientation step for the whipstock with at least initiating the milling procedure for the window. The technique involves the use of measurement-while-drilling (MWD) equipment in the bottomhole assembly when introducing the whipstock, its

support, and at least a starter mill for forming the window. However, the MWD equipment requires significant circulation rates, while the anchor or packer or bridge plug used to support the whipstock would normally require pressurization in order to be set. Thus, what has evolved is a combination bypass valve in the bottomhole assembly which permits high circulation through the MWD equipment for orientation of the whipstock. At the same time, this equipment, through the bypass valve closing, in turn allows pressurization for setting a packer, bridge plug or anchor once the desired orientation for the whipstock has been obtained.

One such device is illustrated in U.S. Patent 5,443,129, invented by *Bailey*. This design has several shortcomings. The bypass valve is in the bottomhole assembly as the lateral is being drilled. Each time another stand is added to the string for drilling the lateral, the bypass valve in *Bailey* strokes between open and closed. This characteristic can allow cuttings from the annulus to enter the circulation port each time it opens, thus potentially precluding it from reclosing so as to again permit circulation to go down to the bit. Without circulation down to the bit, any further drilling of the lateral is prevented. This situation, if undetected, can also lead to sticking the bit due to low or no circulation to take cuttings away from the bit. Another potential problem of the *Bailey* design is that a floating piston is used to separate the hydraulic setting mechanism of the packer from the circulation flowpath within the bypass valve. Thus, if blockages to circulation occur through the bypass valve, a pressure build-up on the floating piston can occur, setting the packer or bridge plug at an inopportune time.

Thus, one of the objects of the present apparatus and method is to be able to properly orient a whipstock, using a bypass valve in the bottomhole assembly where the setting system for the packer or bridge plug is effectively isolated from the circulation flowpath to avoid inadvertent settings of the packer or bridge plug which functions to anchor the whipstock. Yet another objective is to design a bypass circulation valve which, after obtaining the desired orientation of the whipstock, can close to circulation required for MWD operation and maintain the MWD circulation port in the closed position. This gives assurance during subsequent drilling of the lateral that the bypass valve will not stick in the bypass position, thus creating a potential for sticking the bit.

Traditionally, mills have been attached to the whipstock using a lug with a shearable connection to the milling assembly. This has created problems in the past because the shear pin holding the milling assembly to the lug might not release at the predetermined level of force indicated by the manufacturer. At times, in order to run in the bottomhole assembly, forces are applied which could result in an inadvertent premature release between the whipstock and milling assembly at this shear pin. Thus, another objective of the present invention is to improve the connection between the milling assembly and the whipstock so that the assembly could be run into the wellbore with a greater degree of comfort that a premature release will not occur. Thus, the objective of the new technique is to effectively sandwich in the starter mill to the whipstock to allow the use of sturdier connections to eliminate or reduce the risk of an inadvertent release during run-in. Release of the mill from the whipstock occurs simply by rotating the mill after releasing a rotational lock. These objectives will

be more readily appreciated by those skilled in the art from a review of the description of the preferred embodiment below.

SUMMARY OF THE INVENTION

A one-trip apparatus and method involves a bypass valve operated in conjunction with an MWD tool in a bottomhole assembly. The milling system for the window, the whipstock, and the anchor are run in together with the bypass valve and MWD tool. The whipstock is oriented using the MWD tool with circulation through the bypass valve. The bypass valve is actuated to close and locks closed to allow subsequent setting of the packer or bridge plug once the whipstock has been properly oriented. The mills are supported to the whipstock between a pair of lugs and rotationally locked to one of the lugs. Pressure at a predetermined level releases the rotational lock and mere rotation of the mills allows for formation of the window as the lower lug is milled away. The mills are held to the whipstock with pins through the blocks which are capable of handling greater shear loads than shear pins which have in the past been used to secure the mills to the whipstock.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1a-d are a sectional elevation in split view of the bypass valve to be mounted below the MWD equipment in a bottomhole assembly, showing the bypass and flow through positions.

Figures 2a-b are a sectional elevation showing the milling assembly as it is being sandwiched between lugs connected to the whipstock.

Figures 3a-b show the milling assembly fully connected to the whipstock for run-in.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Those skilled in the art of window milling will appreciate that Figures 1, 2 and 3 do not show all the components of a bottomhole assembly for one-trip window milling. Certain standard known components of such a bottomhole assembly have been omitted from the drawings for clarity. Beginning with the lower end of the bottomhole assembly, the lowermost illustrated component in Figure 2 is the whipstock **10** which has a tapered guide surface **12** to direct the movement of the milling system **14**. Connected below the whipstock **10** but not shown is a packer or bridge plug or some other anchor which is preferably hydraulically set through pressure applied through tube **16**. While tube **16** is cut off in Figures 2 and 3, those skilled in the art will appre ciate that it goes to the setting mechanism for a packer, bridge plug or anchor which will support the whipstock **10** when the proper orientation of guide surface **12** has been determined by the MWD tool which is also not shown. Referring to Figure 1a, the MWD tool would be typically connected above thread **18** so that flow through the MWD tool goes through passage **20**. Figures 1a-d illustrate the bypass valve **22** in its two positions. Passage **20** communicates with a piston **24** which has an orifice **26** secured near top end **28**. Piston **24** has a bore **30** which communicates through ports **32** to outlet ports **34** on body **36**. O-ring seal **38** is mounted to the piston **24** adjacent top end **28** and seals between the piston **24** and the body **36**.

O-ring 40 is also mounted between the piston 24 and body 36 adjacent port 32.

A shear pin 42 secures the piston 24 to the body 36 during run-in. Piston 24 has a lower end 44 (see Figure 1b) on which spring 46 provides an upward bias. Spring 46 is supported from surface 48 of choke plug 50. Choke plug 50 rests on bottom sub 52 and is held against it at surface 54 due to the reaction force to spring 46.

Piston 24 has a choke sleeve 56 which is mounted within bore 30 of piston 24. The choke sleeve 56 is connected to the piston 24 for tandem movement. O-ring 58 seals between the piston 24 and choke sleeve 56. Bore 30 in piston 24 is obstructed by closed end 60 of choke sleeve 56. O-ring 62, when in contact with surface 64 on choke sleeve 56, effectively seals off bore 30 for the run-in position. The run-in position incorporates alignment of ports 32 with outlet ports 34. Choke sleeve 56 also has a bore 66 which begins at its lower end 68 and extends to an upper end 70. In between ends 68 and 70 are a plurality of openings 72 which allow flow from annular space 74 to exit through bore 66 by passing through openings 72. The necessary movements to allow such flow to occur will be described below.

Piston 24 has an O-ring seal 76 adjacent its lower end 78. Body 36 has a raised surface 80 with which seal 76 comes in contact upon movement of piston 24, as shown in a portion of Figure 1b.

Attached to body 36 by pin or pins 82 is a collet sleeve 84. A snap ring 86 is carried by piston 24 against collet sleeve 84. Ultimately, as shown in Figure 1a, the snap ring 86 straddles the top end 88 of collet

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sleeve **84** while engaging sleeve **24** at surface **90**, thus locking in upward movement of the piston **24** as will be described below.

Body **36** also has a series of openings **92** which permit outward fluid displacement from body **36** as piston **24** is stroked upwardly. The presence of openings **92** also prevents surges of pressure to the packer or bridge plug or anchor below (not shown) as the piston **24** strokes upwardly, bringing O- ring **76** in contact with surface **80**.

The major components of the bypass valve now having been described, its operation will be reviewed in greater detail. The bypass valve **22** is run in with the piston **24** in the down position, compressing spring **46** and being held in that position by pin or pins **42**. With the piston **24** in that position, the ports **32** line up with outlet ports **34** to allow circulation from the surface through the MWD tool (not shown) and into passage **20**. Thereafter, flow goes through the nozzle **26** into bore **30**. Thereafter, the flow exits ports **32** into outlet ports **34** and into the annulus for a return to the surface. Closed end **60**, due to the O-ring seal **62** being disposed against surface **64**, effectively closes off the lower end of bore **30**. Once the proper orientation for the whipstock **10** has been obtained, flow is increased through passage **20** which creates an incre mental downward force through nozzle **26** on piston **24**. Eventually, that force rises to a predetermined level to break the shear pins **42**. Piston **24** can move down only until shoulder **94** (see Figure 1a) hits the top end **88** of collet sleeve **84**. This downward movement causes a partial misalignment between ports **32** and outlet ports **34**. This is seen as a pressure increase at the surface to allow surface personnel to know that the shear pins **42** have

broken. There after, the rig pumps are turned off, now allowing spring **46** to bias the piston **24** and with it, choke sleeve **56**, in an upward direction. Since choke plug **50** remains stationary, surface **64** moves away from O-ring **62** to clear a pas sage **96** around closed end **60**. As passage **96** is developing due to relative movement between the choke plug **50** and the choke sleeve **56**, O-ring **76** is moving closer to surface **80**. Fluid is thus being displaced out of openings **92** to prevent a surge of pressure to the packer or bridge plug or anchor (not shown) upon initial movement of the piston **24**. Upon sufficient upward movement of the piston **24**, O-ring **40** crosses outlet ports **34** and O-ring **76** contacts surface **80**. Outlet ports **34** are now effectively sealed off by virtue of O-ring seals **40** and **76**. The snap ring **86** snaps radially outwardly above the top end **88**, straddling it and engaging at the same time surface **90** on piston **24**, thus preventing any return movement of the piston **24** once fully stroked to the closed position. Once all the above-described movements have occurred, the pumps are turned on at the surface and flow resumes through passage **20** down passage **96** into annular space **74**. From there, the flow passes through openings **72** into bore **66** and out through passage **98** in bottom sub **52**. Bottom sub **52** has threads **100**. Connected to threads **100** are connectors (not shown) which ultimately secure the bottom sub **52** to threads **102** (see Figure 2b) of the milling system **14**. Passage **98** and bottom sub **52** continue as passage **104** in the milling system **14**.

Referring now to Figures 2a and b, the guide surface **12** of the whip stock **10** has a lower block **106** which is preferably made of brass, solidly secured to it. Lower block **106** has a lower bore **108** which has a thread **110**. Tube **16** has a sliding sleeve **112** which is movable with respect to

tube **16** and is sealingly attached to it by virtue of O-rings **114** and **116**. Sliding sleeve **112** has a thread **118** which can be engaged to thread **110** of lower block **106**. Lower block **106** has an upper bore **120** adjacent lower bore **110**. With the telescoping sleeve **112** in a down position, tube **122** can be inserted from lower bore **108** into upper bore **120** and its position can be secured to the lower block **106** through a shear pin **124**. Thus, in the position shown in Figure 2, sleeve **122** is sealingly secured in bore **120** of lower block **106** by virtue of O-ring seals **126** and **128**. Sleeve **122** is also secured in bore **130** of the milling system **14** by virtue of O-ring seals **132** and **134**.

Sleeve **122** has an internal bore **136** which narrows at taper **138**. Thus, with the sleeve **122** extending both into bore **120** of lower block **106**, as well as bore **130** in the milling system **14**, the milling system **14** is rotationally locked to the whipstock **10** since the lower block **106** is fixedly mounted to the guide surface **12**. However, the rotational lock can be released upon suffi cient flow through passage **104**. In view of taper **138**, a sufficiently large unbalanced force is eventually created against the shear pin **124**, which allows it to break. Thereafter, again because of taper **138**, the sleeve **122** is propelled downwardly and retained within sliding sleeve **112**. The downward movement of sleeve **122** brings it out of bore **130**, thus releasing the rotational lock between the milling system **14** and the whipstock **10**.

The whipstock **10** also has a movable upper block **140** which is secured to the guide surface **12** initially by a fastener **142**. The whipstock **10** has an opening **144** which can accept a stud **146** when a threaded passage **148** is brought into alignment with it. Accordingly, when the

milling system **14**, which has a plurality of cutting blades **150**, each of which has a plurality of inserts **152** disposed in a known manner, is to be connected to the whipstock **10**, one of the blades **150** is brought down in contact with sloping surface **154** on lower block **106**. Fastener **142** is removed, allowing upper block **140** to descend until threaded passage **148** is in alignment with opening **144**. At that point, bolt or stud **146** is inserted and secured into upper block **140**, thus not only securing the position of upper block **140** to the whipstock **10** but also at the same time sandwiching in the blade **150** as sloping surface **156** on the upper block **140** engages the top sloping surface **158** on the blade **150**. In the position shown in Figures 3a and b, the milling system **14** is firmly secured through the blade **150** between the upper block **140** and lower block **106**. In order to set the packer, bridge plug or anchor (not shown), the bypass valve **22**, shown in Figure 1, must be put in the position where outlet ports **34** are closed. A subsequent pressure build-up will initiate flow to the packer through tube **16**. When the flow increases to a predetermined level, the shear pin **124** is broken, allowing the sleeve **122** to come out of bore **130**. At that point, the rotational lock between the milling system **14** and the whipstock **10** is released. Rotation of the milling system **14** by whatever means can then begin. As rotation begins, the lower block **106** is milled away and the guide surface **12** directs the milling system **14** into the adjacent casing to mill the window and lateral in the known manner.

The advantage of this system is that the use of shear pins to retain the milling system **14** to the whipstock **10** is eliminated. Instead, a solid screw, stud or bolt **146** is used whose ability to withstand shear loading is substan tially higher than normally used shear pins. Sleeve **122** is also a

robust rotational lock which facilitates manipulation of the bottomhole assembly for run-in. Thus, if manipulation of the bottomhole assembly is required for run-in, there is little or no risk of a premature release in the manner in which the milling system **14** is retained to the whipstock **10**. Raising or lowering is also unnecessary to release the milling system **14** from the whipstock **10**. The milling system **14** is merely rotated as the bottom block **106** is milled away and the milling of the window proceeds in the known manner.

Figures 4 and 5 illustrate alternative embodiments to secure the milling system **14_**. In the Figure 4 design, the sleeve **122_** is made relatively weak, and the principal resistance to applied torque is provided through a tab or tabs **160**, which engages one of the cutting blades **150_**. The tab **160** can be connected to the guide surface **12_**. It can be used in conjunction with a torsion bolt **162** which extends through upper block **140_**. With the sleeve being made of a fairly thin material in the Figure 4 embodiment, release from the whipstock **10_** can still be accomplished if for any reason the sleeve **122_** does not get expelled in the manner previously discussed. The sleeve **122_** can be made of sufficiently thin material so that flow through passage **104_** can simply erode it, or alternatively the milling system **14_** can be simply rotated to break the sleeve **122_** along with tab **160**, if used, and/or torsion bolt **162**, if used. Figure 5 illustrates an alternative embodiment for the lower block **106_**, indicating that a projecting segment **164**, which houses the sliding sleeve **112_**, can be made in such a manner that rotation of the milling system **14_** will simply snap off the extending segment **164** off the lower block **106_** at

a predetermined torque value to allow the milling of the casing to make the window. Thus, in both embodiments in Figures 4 and 5, the sleeve **122_** can be made sufficiently weak so that it can either be eroded away or sheared cleanly by initiation of rotation of the milling system **14_**. This is to be contrasted with the embodiment of Figures 2 and 3, where the sleeve **122** is the principal rotational lock and, therefore, must be expelled out of the way to facilitate release of the milling system **14**. The system of Figures 4 and 5 provides a different way to rotationally lock the milling system **14_** by use of either a tab **160** secured to the guide surface **12_**, used alone or in conjunction with a torsion bolt or bolts **162** which provide the principal rotational lock. The sleeve **122_** may also offer some minimal rotational resistance, but in the embodiment of Figure 4 is reasonably weak so that it can be sheared off with rotation of the milling system **14_**. In the embodiment of Figure 5, the level of resistance to applied torque is determined by the design of the lower block **106_** and the area of the ultimate shear plane as the extending segment **164** is sheared off the portion of the lower block **106_** which is, in turn, secured to the guide surface **12_**.

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made without departing from the spirit of the invention.

Claims

1. A valve assembly for downhole use comprising:

a body having a passage therethrough and a lateral port;

a valve member movable from an open position where said passage below said lateral port is obstructed and said lateral port is open, to a closed position where said lateral port is closed and said passage below said lateral port is open;

said valve member locking upon reaching said closed position.

2. The valve assembly of claim 1, further comprising:

a vent opening in said body to allow for fluid displacement therethrough as said valve member moves toward its said closed position, said vent opening being obstructed by said valve member in said closed position.

3. The valve assembly of claim 1, wherein:

said valve member is movably responsive to fluid flow in a first direction and in an opposite second direction under a biasing force.

4. The valve assembly of claim 3, wherein:

said valve member when moving in said first direction obstructs, at least in part, said lateral port

while maintaining said passage below said lateral port closed thus causing a pressure buildup in said body as an indication of movement of said valve body in said first direction.

5. The valve assembly of claim 4, wherein:

said valve member is initially retained against a spring bias by a breakable member;

said valve member comprises a passage having a flow restriction;

said body comprises a plug which obstructs said passage in said valve member in said closed position;

whereupon sufficient flow induced force on said valve member, said breakable member breaks as said valve member moves to at least partially obstruct said lateral port, whereupon removal of said flow induced force on said valve member said spring moves said flow passage in said valve member away from said plug which opens said passage in said body below said lateral port and moves said valve member over said lateral port.

6. The valve assembly of claim 5, further comprising:

a vent opening in said body to allow for fluid displacement therethrough as said valve member moves toward its said closed position, said vent opening being obstructed by said valve member in said closed position;

said body comprising a springing lock to secure said valve member to said body in said closed position.

7. In a one trip window milling assembly which comprises an orientation tool, at least one mill, a whipstock, a pressure activated anchor and a bypass valve which selectively allows circulation for operation of the orientation tool and for the direction of pressure to said anchor to activate it, the improvement in said valve comprising:

a body having a passage therethrough and a lateral port;

a valve member movable from an open position where said passage below said lateral port, extending to said anchor, is obstructed and said lateral port is open, to a closed position where said lateral port is closed and said passage below said lateral port extending to said anchor is open;

said valve member locking upon reaching said closed position.

8. The valve assembly of claim 7, further comprising:

a vent opening in said body to allow for fluid displacement therethrough as said valve member moves toward its said closed position to prevent pressure buildup on said anchor, said vent opening being obstructed by said valve member in said closed position.

9. The valve assembly of claim 7, wherein:

said valve member is movably responsive to fluid flow in a first direction and in an opposite second direction to a biasing force.

10. The valve assembly of claim 9, wherein:

said valve member when moving in said first direction obstructs, at least in part, said lateral port while maintaining said passage below said lateral port closed thus causing a pressure buildup in said body which pressure buildup is isolated from said anchor, as an indication of movement of said valve body in said first direction.

11. The valve assembly of claim 10, wherein:

said valve member is initially retained against a spring bias by a breakable member;

said valve member comprises a passage having a flow restriction;

said body comprises a plug which obstructs said passage in said valve member in said closed position to isolate said anchor from applied pressure;

whereupon sufficient flow induced force on said valve member, said breakable member breaks as said valve member moves to at least partially obstruct said lateral port, whereupon removal of said flow induced force on said valve member said spring moves said valve member away from said plug which opens said passage in said body below said lateral port to said anchor and moves said valve member over said lateral port.

12. The valve assembly of claim 11, further comprising:

a vent opening in said body to allow for fluid displacement therethrough as said valve member moves

toward its said closed position to prevent pressure buildup on said anchor, said vent opening being obstructed by said valve member in said closed position;

said body comprising a springing lock to secure said valve member to said body in said closed position.

13. A rotational lock system to secure a mill to a whipstock comprising:

a lug having a passage therethrough secured to the whipstock;

a tube extending from a flow passage in the mill and into said passage in said lug;

said tube selectively displaceable out of said flow passage in the mill to rotationally release said mill.

14. The system of claim 13, wherein:

said lug contacts said mill from below and a retainer is mounted to said whipstock opposite said lug to retain said mill longitudinally to said whipstock.

15. The system of claim 14, wherein:

said retainer is secured to said whipstock by a stud or bolt.

16. The system of claim 13, further comprising:

a telescoping conduit selectively securable to said passage in said lug, said conduit configured to retain said tube after it is expelled from said lug.

17. A rotational lock system to secure a mill to a whipstock comprising:

a lug having a passage therethrough secured to the whipstock;

a tube extending from a flow passage in the mill and into said passage in said lug.

said tube is made of a sufficiently thin wall so that it can be eroded with flow going through it or sheared apart by mill rotation; and

a tab mounted to said whipstock engaging said mill to resist rotation.

18. The system of claim 17, further comprising:

a retainer to secure said mill against said lug, said retainer secured to said whipstock by a bolt or stud.

19. The system of claim 18, wherein:

said tab, said lug and said tube, if it still extends from said mill into said lug, are removed by operation of said mill.

20. A rotational lock system to secure a mill to a whipstock comprising:

a lug having a passage therethrough secured to the whipstock;

a tube extending from a flow passage in the mill

and into said passage in said lug.

said passage in said lug is disposed on a projecting segment thereof disposed away from said whipstock, such that rotation of said mill separates said protecting segment from the balance of said lug.

21. A window milling assembly comprising a mill and a whipstock, wherein the mill is retained longitudinally between a pair of lugs connected to the whipstock, and wherein the mill is retained rotationally by a releasable lock connected to the whipstock, such that on release of the lock the mill can rotate to allow formation of a window as the lower lug is milled away.

INVESTOR IN PEOPLE

Application No:	GB 0001480.3	**Examiner:**	Matthew Parker
Claims searched:	1-12	**Date of search:**	8 May 2000

Patents Act 1977
Search Report under Section 17

Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

UK Cl (Ed.R): E1F: FLF, FLP

Int Cl (Ed.7): E21B: 21/10, 34/10, 34/16

Other: Online: EPODOC, JAPIO, WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage		Relevant to claims
X	GB 2334276 A	SCHLUMBERGER LTD	1-2
X	GB 2327691 A	SMITH INTERNATIONAL INC	1-3
X	GB 2307932 A	THE RED BARON LIMITED	1-4

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